Transportation Elements for the Human Lunar Return Study

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Within the Agency's Strategic Plan, Johnson Space Center (JSC) is the lead for implementing the Human Exploration and Development of Space (HEDS) Enterprise. Because of this assigned responsibility, Mr. Daniel Golden, the Agency Administrator, challenged JSC in the fall of 1995 to develop an innovative strategy for returning man to the Moon and beyond at mimimum cost. One response to this request was to immediately open an in-house project at JSC to investigate the issues and opportunities for a manned return mission to the Moon targeted at the year 2002. The project was formally titled the Human Lunar Return (HLR) study and was managed by Elric McHenry of the Technology and Project Implementation Office. The entire project was sponsored by the Advanced Development Office at JSC. Following two prelminary JSC assessments, engineers from MSFC, Lewis Research Center and Langley Research Center were asked to join the team in April 1996. A 4-month study ensued. MSFC was charged with development of selected transportation elements for this more extensive assessment. A baseline lunar reference mission, which utilized the *International Space Station (ISS)* and is believed to be representative of a "minimum" cost return mission, was developed.

In early May 1996, a team was formed within the Program Development Office at MSFC to develop a pre-phase A-level technical design and cost for selected HLR transportation elements. This 4-month task was in response to a request from JSC to support specific aspects of an investigation into a manned return to the Moon. All solutions complied with HLR baseline mission manifest objectives and assumptions developed by the JSC HLR project team. Transportation elements developed included:

- All propulsive elements and associated propellant carrier/transfer kit for the lunar orbit insertion/trans-Earth injection (LOI/TEI) stage which serves as the primary propulsion system for the lunar orbit stage;
- A tandem configured trans-lunar injection (TLI) stage for delivery of the fully integrated lunar orbit stage; and
- A trans-lunar injection/lunar orbit insertion (TLI/LOI) stage for delivery of the lander/habitation module.

Design of the fully reusable propulsive elements of the LOI/TEI stage was completed within 2 months. The design scope included engine selection, propellant requirements, propellant tank sizes, mass breakdown of component parts, materials selected, power requirements, dimensions, schematics, inert stage mass, integration support to JSC, and costs. It is delivered dry to the *ISS* with other mission hardware aboard the Shuttle.

The LOI/TEI stage propellant delivery and transfer system design was completed in less than 1 month from the mid-July 1996 initiation. The design scope included concept selection, operations, configuration, subsystems, mass summary and costs. The LOI/TEI stage propellant carrier/transfer kit is fully reusable and transported to and from the *ISS* via the Shuttle.

The design for the TLI stage was completed in about 2-1/2 months from initiation in early May 1996. The design scope for the TLI stage included an assessment of configuration and deployment options, trades, concept selection, a systems analysis defining the various subsystems required, performance analyses, timelines, configurations, mass statements, schedules and costs. The TLI stage is required to provide the transportation for placing the lunar orbit stage assembly consisting of the crew module, lander, aerobrake and LOI and TEI stage on a lunar trajectory which allows insertion into lunar orbit by the LOI/TEI stage. It is configured as tandem, pump-fed (main engine) expendable cryogenic stages. Once mated to the lunar orbit stage, the subsequent assembly becomes the lunar stack. Stage delivery is accomplished via two Proton-M launches.

The TLI/LOI stage for the lunar lander/habitat module was completed in less than 1 month following a mid-July 1996 start. The scope of the design included mission profile, performance analyses, configurations, timelines, subsystems, mass and costs. The TLI/LOI stage is expendable, and was derived from the TLI stage 2 design. It performs the TLI burn, midcourse corrections, coasts to the Moon and then brakes the lander/habitat module into low-lunar orbit with a single burn of the main engine.

This internal Agency study dealing with human lunar return concluded in August 1996. Included in the results were: a description of the top level vehicle elements; what we want to do at the Moon; and the kinds of lunar resource development and science that could be performed.

All assigned transportation elements were delivered on schedule with a high level of detail. Center to center coordination was excellent. The baseline HLR mission cost was estimated at between $3 to 5 billion or equivalent to about 2 to 5 percent of the Apollo missions and could be implemented within a 3- to 5-year time frame. The baseline implementation plan made maximum use of existing launchers, commonality of hardware design, inclusion of new or emerging technologies, and sought to maximize reusability where beneficial. A cursory investigation was given to a possible alternate mission scenario which departed from the *ISS* but returned directly to Earth. This appears to offer somewhat lower mission costs and the easiest access to all possible lunar surface landing sites. The area of greatest scientific value appears to be the polar ice region.

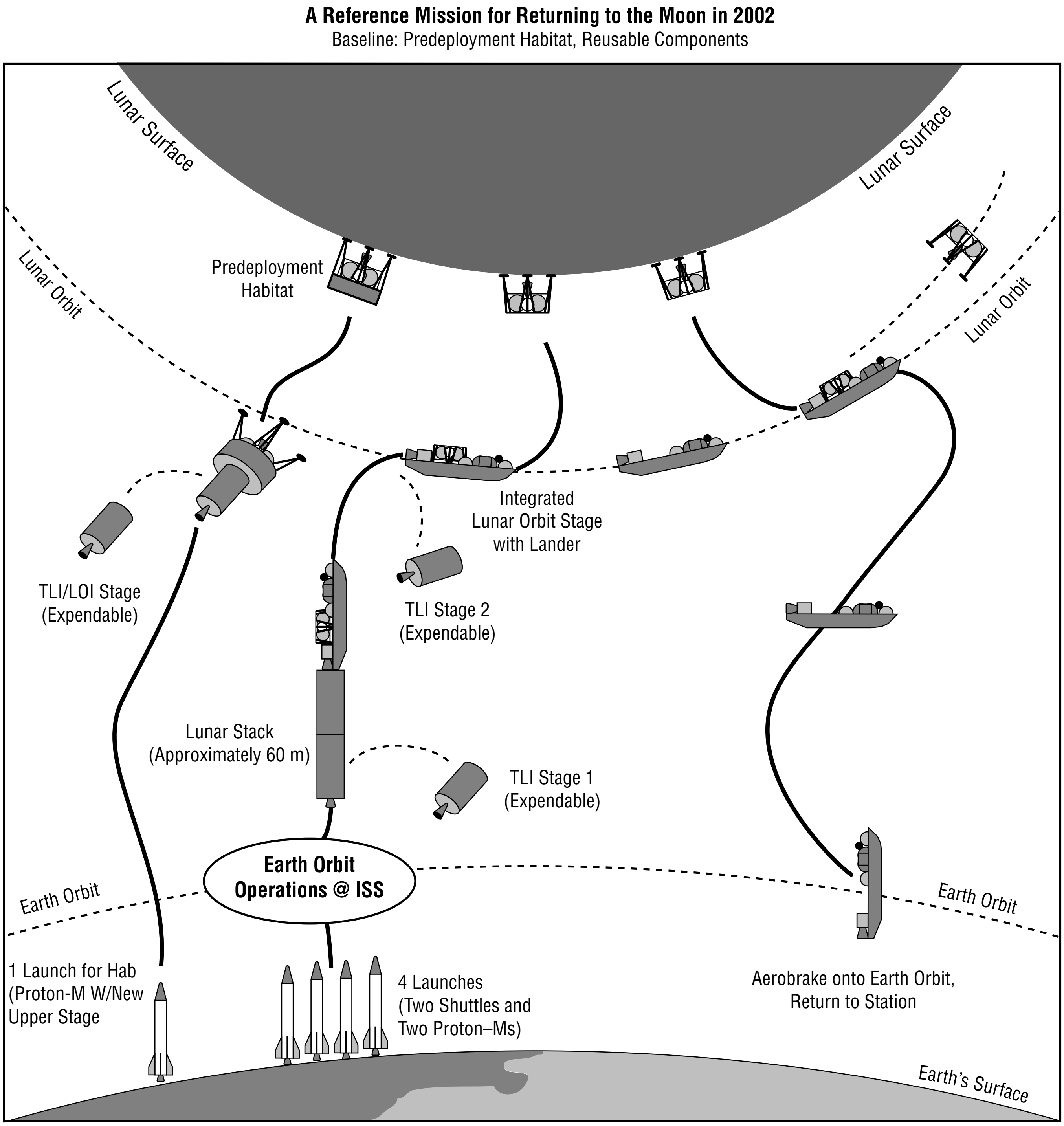

Figure 186.—Design Reference Mission (2002). Baseline: predeployed habitat, reusable components.

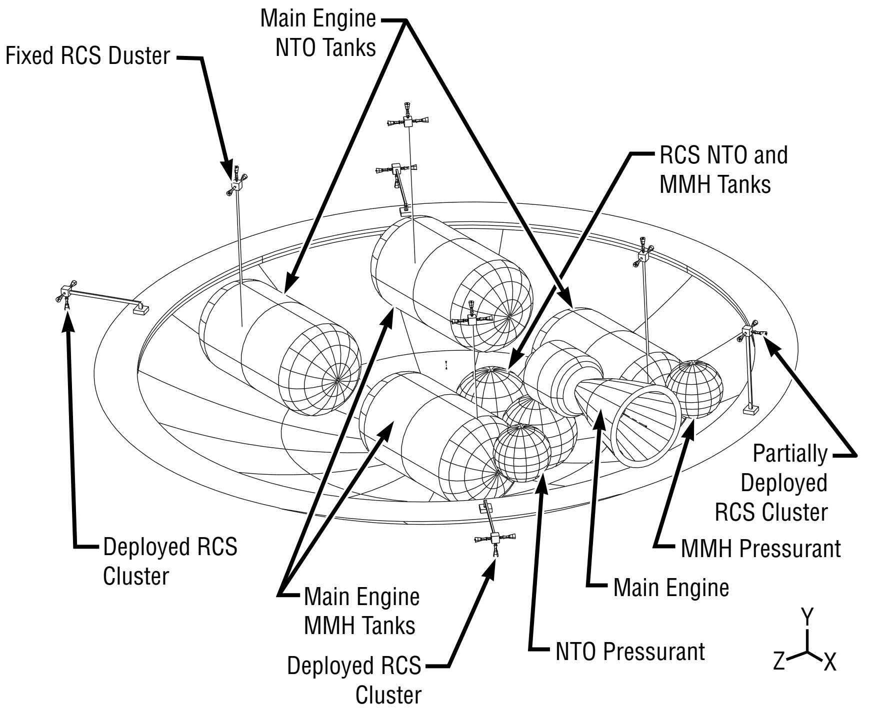

Figure 187.—LOI/TEI propulsive elements.

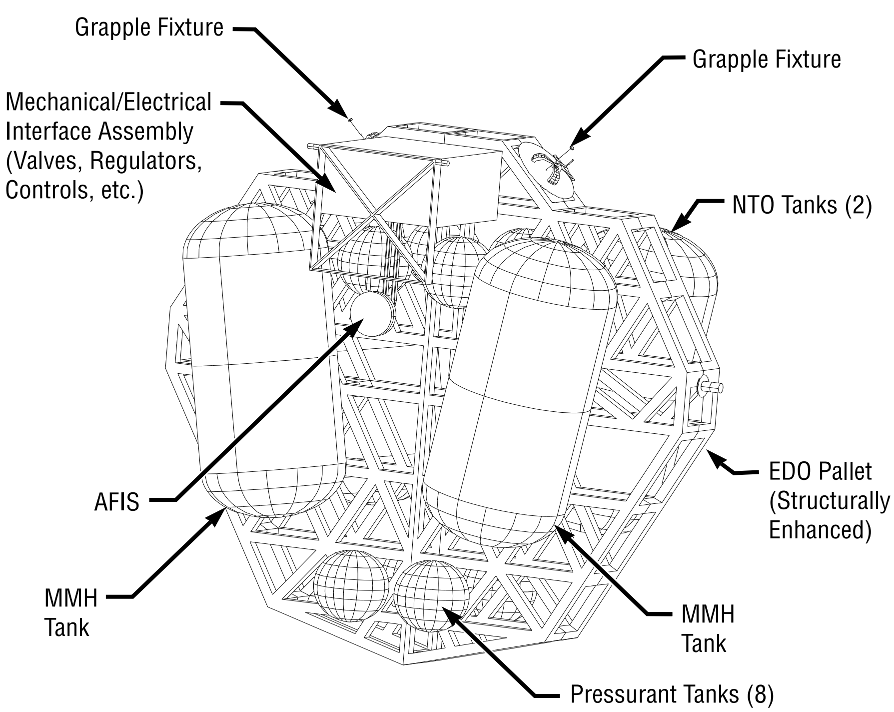

Figure 188.—LOI/TEI propellant carrier/transfer kit.

Landing here would drive any developed transportation architecture. It would therefore be best if the final transportation architecture for any manned missions be made following analysis of data obtained by robotic rovers sent to the polar region.

Sponsor: Johnson Space Center—Advanced Development Office

Biographical Sketches: Mark L. Stucker is a project engineer in the Advanced Systems and Technology Office at Marshall. Since joining NASA in the summer of 1987, he has actively applied technical management skills to propulsion technology projects dealing with solid, liquid, and hybrid rocket motors. He has served in numerous positions within the Joint Army-Navy-NASA-Air Force (JANNAF) Interagency Propulsion Committee and was cited in 1993 for outstanding contributions to chemical propulsion technology and service to JANNAF. Stucker received his BSIE and MSIE from the University of Tennessee in Knoxville in 1974 and 1975.

Thomas D. Dickerson is the Mission Analysis team leader in the Preliminary Design Office of the Program Development Directorate at the Marshall Space Flight Center. He served as the lead engineer for the Human Lunar Return study. Dickerson is a 1962 graduate of Middle Tennessee State University and has 34 years experience with NASA. His technical background is in launch vehicle trajectory and performance analysis and orbital mechanics. During his career with NASA, he has served as the lead engineer for other projects including the Aeroassist Flight Experiment, Earth Science Geosynchronous Platform, Aerobrake Design for Lunar Return Vehicles, High Temperature Materials Processing Furnaces for the Space Station Furnace Facility and others.

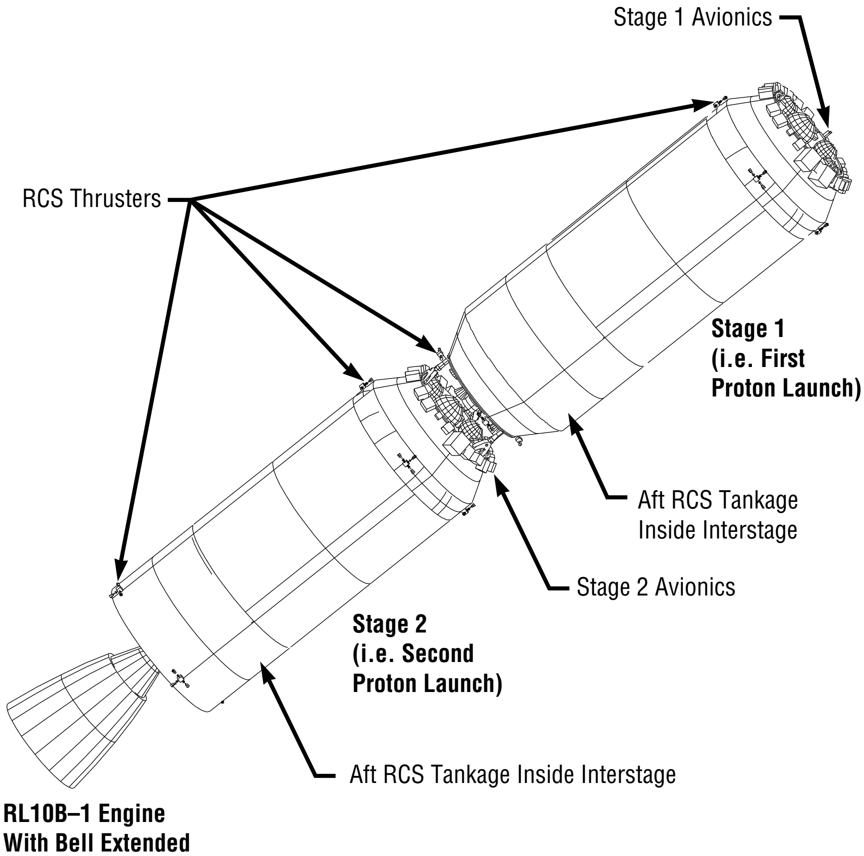

Figure 189.—Tandem translunar injection (TLI) stages.

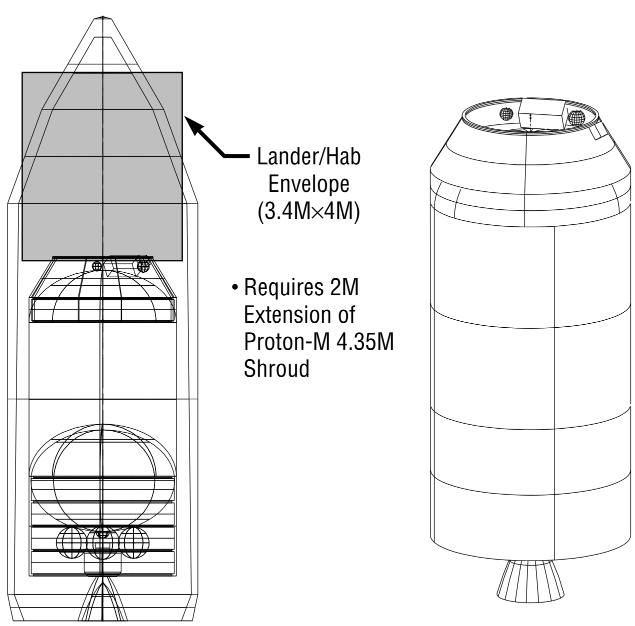

Figure 190.—TLI/LOI stage configuration for lander/habitat.